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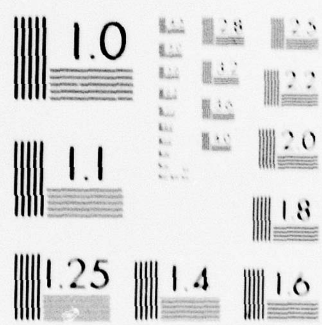

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CIVIL ENGINEERING LABORATORY
Naval Construction Battalion Center
Port Hueneme, California

Sponsored by

NAVAL FACILITIES ENGINEERING COMMAND

SURVEY OF NAVAL PORT FENDER SYSTEMS

January 1980

An Investigation Conducted by

VSE CORPORATION
Oxnard, California

N00123-78-C-0391

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A survey of Navy pier fender systems was conducted to evaluate the need for an RDT&E program leading to improved fender systems. Eighteen major activities were surveyed by mail and on-site visits were made to activities in San Diego and Norfolk.

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The survey revealed:

a. An overall poor to fair condition for pier fender systems except where repair by replacement was being accomplished by large scale projects.

b. A trend towards increasing costs and a declining quality of timber materials.

c. An overriding concern for the frequency and magnitude of damage by ships and craft.

d. A uniformity in problems, damage and level of maintenance costs but a lack of uniformity in approaches to improvements and solutions.

e. Improvements in design and materials for timber pile fender systems in San Diego that may well be applicable to general purpose berthing at most other locations.

f. A need for concentrated, centralized work to improve camel and fender designs for submarines, carriers and certain special use berthing.

Recommendations resulting from the survey include:

a. That no RDT&E effort is needed for general purpose berthing, but coordinated facilities acquisition and management efforts are needed to evaluate and implement certain specific improvements in timber pile systems.

b. RDT&E work in the near time-frame for dedicated submarine, CV/LHA and certain special use berthing.

c. Initiation of a long-range study that looks to the time when wood products may not be available in the quantity and quality now depended upon for ship fendering.

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EXECUTIVE SUMMARY

In response to indications from the Shore Establishment that pier fender systems are absorbing an inordinate share of MRP funds/effort, CEL initiated this survey. The purpose was to determine the current condition/status of fender systems, the extent and major causes of damage, maintenance and repair costs and level of effort, and indicated trends. The objective to be served by the survey is to assist CEL in evaluating the need for and potential of RDT&E projects to improve fender systems.

The survey encompassed a mail survey of 18 major activities/complexes and on-site visits to all activities in San Diego and Norfolk. In addition, a review of previous related studies and recent Navy fender designs was accomplished. The survey revealed:

- a high level of interest at activity level in fendering costs and problems and in any technical help that will improve the current situation.
- an overall poor to fair condition, except where repair by replacement was being accomplished by large scale projects, and trends toward increasing costs, declining quality of timber materials, and a requirement for increasing levels of effort.
- an overriding concern for the frequency and cumulative magnitude of damage to fender systems by ships and craft.
- relative uniformity in fender system problems, damage and level of maintenance costs, but a lack of uniformity in approaches to improvements/solutions. No 'Navy approach' to fendering is evident.
- improvements in design and materials for timber pile fender systems in San Diego that may well be applicable to general purpose berthing at most other locations.
- a need for concentrated, centralized work to improve camel-fender designs for submarine, aircraft carrier and certain special use berthing.

Recommendations resulting from the survey include:

- no RDT&E effort for general purpose berthing, but coordinated facilities acquisition and management efforts to evaluate and implement certain specific improvements in timber pile systems - heavier design, improved material procurement, use of large rubber energy absorbing units, improved pile alignment, more widespread tests of log camels.
- RDT&E work in the near time-frame for dedicated submarine, CV/LHA, unconventional hulled ship, and certain special use berthing.
- initiation of a long-range study that looks to the time when wood products may not be available in the quantity/quality now depended upon for ship fendering.

SECTION I

INTRODUCTION

1.0 OBJECTIVE

The survey is to provide data, information, conclusions and recommendations concerning Navy fender systems currently in use to assist the Civil Engineering Laboratory (CEL) in evaluating the need for and potential of RDT&E projects for future fender systems.

1.1 BACKGROUND

The U.S. Navy owns a large number of piers and invests millions of dollars annually in fendering to protect both the piers and ships berthed. The Naval Facilities Engineering Command (NAVFACENGCOM) provides design and construction of all new facilities and has a responsibility to provide technical guidance and direction to shore activities in the maintenance and repair of facilities. As the NAVFACENGCOM agent for research, development, test and evaluation, the Civil Engineering Laboratory has historically been involved in studies and projects concerning waterfront facilities including fender systems. The last comprehensive effort by CEL in this area was in the mid-1960's, the written documentation of which is briefly reviewed in paragraph 2.3 of this report. No significant changes in fender system designs have been implemented for many years.

There are strong indications that the Navy ports are having to expend an increasing amount of maintenance and repair funds and effort on the fendering function while making no headway. There are no indications that a change to this trend is in sight. The opinion heard from the 'grass roots' level is that there must be a better way. Consequently, VSE Corporation was tasked by CEL, under the Statement of Work in appendix A, to perform a survey with the objective stated above.

1.2 PURPOSE

The interrelated purposes of the survey were to:

a. Obtain information and data on:

- design related fender problems
- maintenance related fender problems
- ship (mechanical) damage of fenders
- maintenance and repair costs and backlog

b. Analyze the information to determine:

- commonality of problems at naval activities
- unique problems
- magnitude and nature of ship damage

- the overall cost of maintaining fender systems
- downtime, length of life, etc.

c. Draw conclusions from the analysis concerning:

- the adequacy of current Navy fender systems
- factors contributing to mechanical damage and potential for control or correction
- the cost of maintaining current systems related to the function being performed and to probable alternatives
- the potential direction and benefit of a RDT&E project aimed at improved design, lower life cycle costs, longer life, and lower maintenance cost.

Areas the survey was not intended to cover included analysis of fender design criteria, survey of various fender systems in use by other than naval activities, and any extensive survey of environmental damage to fender systems.

In summary, the survey was designed to assist in the identification and definition of current fendering problems and in the evaluation of the potential success of a research project in the context of economic reality.

1.3 METHOD OF APPROACH

The survey was conducted through a mail survey, limited on-site surveys of naval activities, and a review of other studies accomplished in similar technical areas. Section II reports the results of the surveys and literature review with the following sections providing discussion, analysis, conclusions and recommendations.

SECTION II

INFORMATION AND DATA

2.0 GENERAL

Information for this survey was obtained from on-site surveys accomplished in San Diego and Norfolk and through a mail survey of a large proportion of the naval activities having waterfront facilities. In addition, a review was made of CEL provided literature pertaining to previous studies of fender systems and related problems.

The time frame for this report precluded the more extensive on-site surveys originally planned; Long Beach, CA, Bremerton, WA, and Pearl Harbor, HI. If further and more detailed work is done following this survey, additional on-site visits and requests for mail input should be included. Specifics are addressed in Section IV.

2.1 MAIL SURVEY

In addition to the on-site surveys discussed in paragraph 2.2, a mail survey was conducted to obtain information and cost data from naval activities having significant waterfront facilities and berthing activity and to obtain input from NAVFAC Engineering Field Divisions (EFD). Survey information/data forms and a list of activities surveyed are contained in appendix C.

2.1.1 Naval Activity Input. The mail survey covered 18 activities excluding the San Diego area, 15 of which responded. Due to the scheduled on-site visit, San Diego activities provided no input to the mail survey. Norfolk activities participated because the on-site survey developed later.

In addition to the approximately 234 ships homeported at activities covered by the on-site surveys in San Diego and Norfolk, there are an additional 140+ ships homeported at other activities responding to the survey. Accordingly, the survey covered a large portion of the Navy's potential berthing problems and generated response that indicates significant interest and concern in these fender system problems.

The following excerpts and paraphrased statements were extracted from input most pertinent to this study. The information is given in this format so that a reading will provide a picture of the fender system situation at a large representative cross-section of naval activities.

a. Submarine Base, New London, CT.

- 11 of 13 piers have standard design wood pile fender systems, one pier berths ARD's and requires no fendering, and one pier has a newly designed steel H pile system with resilient bumpers.

- As wooden piers were phased out in the late 50's, wooden fendering systems were designed for new concrete piers...systems were designed for World War II type diesel submarines which were quite maneuverable...proved quite serviceable for this type of submarine except for an occasional accident when the submarines made a particularly bad approach.

• With introduction of nuclear submarines in early 60's, hull type changed with a single propeller...has very limited maneuverability at low speeds and requires assistance of tugs during docking. Combination of hull formation, increase in tonnage and added horizontal thrust of tugs spelled disaster for the wooden fendering systems...single docking operation frequently wiped out 30 or 40 feet of fendering system by snapping the vertical piles at the mud line and then pulling the anchor bolts out of the pier at the top of the fender pile.

• Design of Pier 32 developed new system to resist loads imposed by nuclear submarines...steel "H" pile system with 1" plate welded on the "H" beam to act as a stiffener. Pier has been in use for one year and no major damage has occurred. Estimated cost of this system is $850/LF.

• 1978 A&E study recommends a hydro-elastic fender system for extreme pressures...cost is about 2.5 times cost of the steel "H" pile system. Under MCON Project P-319 (a FY 80 project) NAVFAC has agreed to fund $250,000 to install a 90' test section on Pier 10...estimated cost $2,000/LF.

b. Philadelphia Naval Shipyard

• Utilizes both hung and pile fender systems...standard designs... adequate where condition of systems is good. Where deteriorated, new designs may be considered...composite steel/wood, new wood treatments, addition of energy absorbing materials behind fenders and chocks.

• Maintenance is limited to checking bolts and fasteners and replacing individual members. Absence of maintenance program due to funding which restricts available equipment necessary...fender system can be made more effective through more comprehensive maintenance program.

• Pile systems last longer than hung systems...typical lifespan varies from 15-30 years.

• No serious damage by ship impact...riverfront location...minimal wave action.

• Hung fenders extend 2'-6" below mean low water...prevents camels from slipping beneath fenders. Also, all bolts on exposed surfaces are setback.

c. Naval Weapons Station, Yorktown, VA.

• Photographs (enclosed with input) show current damage. Any solutions uncovered to reduce $100K/year costs will be appreciated.

• Fender system basically provides protection to pier...damage occurs under certain conditions and fender as installed will not prevent it...ballard snapped by overhang, bow of ammo barge reaches over fender system, barge chafing rail rides on top of piles and bends system away from pier.

• Very little damage from marine borers because piles are damaged by ships and must be replaced before useful life ends.

• All maintenance is performed by contract (no in-house capability) ...averaging $100K/year damage...repairs every third year...main problem is sections of pier left vulnerable to damage between repairs...considering service contract to effect repairs as major damage occurs.

d. Naval Station Norfolk ADHOC Committee Report (Reference 1)

• 10-20% of MRP funds spent on fender systems...averaged $650K/year in past 3 years including special projects...effort is sized to 'keep up' not make headway.

• Many factors contribute to fender pile damage...two major ones: camels and ship handling/tug operations...data that stands out is increase in probability of damage when camels were used...major conclusion was that limiting camel usage should be pursued.

• Treated versus untreated piles...in high impact areas mechanical damage is occurring before biological damage becomes significant. Untreated piles cost one-half as much and are more readily available.

• A 50% cut in camel usage is feasible and could reduce damage by 15-20%, or over $100K/year. The purchase of 30 foot camels should be discontinued.

• One area worth pursuing is use of automatic line tenders.

e. Naval Amphibious Base, Little Creek, VA.

• Damage to fender systems is a major problem at this activity... camels...are the major causes...resources not available to maintain systems or implement alternative systems. Alternative system considered an alteration vice repair...changes to design become a funding problem.

• Piers 1-8 minor mechanical damage...LST/LSD piers 11-19 and quaywalls have had extensive damage...system not designed for cameling-out...nothing prevents camels crushing or snapping pilings.

• Piers 20-34 have received minor damage...corner dolphins can reduce damage. Piers 44-55...almost complete destruction of fender systems and major structural damage to piers...result of large, hard to maneuver causeway sections.

• Mechanical damage has generally destroyed the system long before rot or biological attack affects system integrity.

• Little maintenance performed in anticipation of repair project ...estimated $100K-$200K per year required once major repairs are completed.

f. Charleston Naval Shipyard

- Three types of fender systems are used: timber piles 4-10 feet on center with connecting wales and spacers bolted to pier, steel H-piles with connecting timber wales and spacers used primarily with submarines, and a steel fender pile system with rubber bumpers.

- Steel fender systems have proven very satisfactory, especially those meeting ASTM A590. At the water line, there is a 3' diameter fir log, and at the pier level there is a rubber bumper.

- Existing timber pile fenders rarely ever remain in place long enough to deteriorate from natural causes...broken off beneath the water line as ships are berthed...five or six piles are broken off taking the entire fender system. Timber camels bear on fender piles at the water line which is a weak point.

- Dolphins at outboard corners of piers are easily destroyed... nine to twelve piles wrapped with steel cable, bolted internally and to the pier.

- Damage by ships is by far biggest cause of deterioration (sic)... generally thought that if steel systems were adopted for all piers, maintenance costs would be greatly reduced...high initial cost of steel system discourages use...funds for repair much more available than for new construction.

g. Naval Station, Mayport, FL

- Both fixed and retractable type wood fender systems are in use... relatively short life due to damage and deterioration...normally require replacement in 3 to 5 years...design could be improved to provide greater resistance to impact.

- Systems should also extend to a lower elevation and be more strongly supported at the bottom end. Much of damage occurs at low tide...design change made to timber camels...depth doubled to keep them from riding/being pushed under fender system.

- Wood pile dolphins have short life, have been demolished in as little as one year...new fuel pier design includes steel pile dolphins.

h. Long Beach Naval Shipyard

- 16" butt fender piling used for 34,400 LF of piers...creosote treated. 30"D x 30' long log camels and 4' x 8' bulk camels are used together...bulk camels are used in various combinations to form 4' x 16' sections.

● Recent fast deterioration of piling and camels caused by marine borers...harbor waters cleaner than ever in memory:

Life Expectancy	Polluted	Unpolluted
Piles	8-10 years	2-3 years
Camels	10-15 years	2-3 years

● July 1979 contract to replace 400 fender piles and 167 log camels ...will wrap both with polyethylene...new camels to be 24"D x 47' long... increased length will reduce pile breakage. (From telcon, determined that fender system design will not be changed for this project.)

● New design for aircraft carrier camels...steel, fiberglass flotation...will be 80' long to distribute forces.

● Work by contract is started a year after inspection, during which more work develops...always trying to "catch up".

● If log camels were replaced as needed, ship damage to piers would be reduced by 90%.

i. Mare Island Naval Shipyard

● Present design is considered adequate...no new design is required ...deteriorated fender systems are result of insufficient funds...life of existing systems is considered adequate...new design and new materials is not required. Mare Island continues to be adequately designed berthing facility when sufficient funding and personnel are available for waterfront maintenance.

● No major ship-inflicted damage has been reported. All damage determined to be caused by normal wear and tear.

Comment: The above input notwithstanding, the activity reported maintenance costs of $2 million in FY 78 and $1.6 million in FY 79. It appears there is room for improvement.

j. Public Works Center, Pearl Harbor (Provided input for all Pearl Harbor activities)

● Pilings broken by impact and deterioration...hardware fasteners and components also damaged during impact. Piling failures occur primarily within 12 ft. splash zone near the waterline. Damages are caused by:

(1) Weather changes during docking operations.

(2) Fast docking of ships with tug assistance.

(3) No tug assistance during docking.

(4) Insufficient separators, camels, or others.

- Material life approximately four to five years, but due to heavy usage and operational damage in several areas, requires yearly renewal. Due to design and present condition, maintenance cost to replace piling for upkeep of ships berthing areas is expected to remain high.

- Major problem is outage requirement for replacement of the piling ...difficult to obtain outages for certain berths in constant use...outages are required at high use berths annually because the scope of work must be a compromise of various requirements; availability of funds, priority of repair work, availability of PWC waterfront crews, and operational requirements.

- Shipyard Area - Piers 02 - 14...present design of wooden piling is 5' to 6' spacing...cannot take impact of ships berthing and movements at dock side...broken or damaged fender system makes berthing unsafe and causes damage to ship preservation coating.

- Wharfs K-6 and K-9 not designed for LSD and LST type ships and wharfs K-3, K-5, K-10, and K-11 not designed for MILVAN operations...are being used as such.

- Coordinating piling replacement with pier availability subject to last-minute ship movements; mobilization of repair efforts is costly ...currently costs Naval Supply Center about $850 to replace a single fender pile.

- Overriding problem of piling damage is psychological; ships berthing at Naval Supply Center piers are not responsible for repairing damage to the fender system, so a continued maintenance problem can be expected.

- Barges and miscellaneous ships seem to do most damage...barges with protruding metal lathe strips due to poor ship maintenance tear off large pieces of pilings above the water line... ships with protruding structures berthed without camels cause similar damage.

(Other narrative input consisted of portions from the PACNAVFAC Waterfront Facility Study which is discussed under EFD input.)

The following are excerpts from a PWC, Pearl Harbor letter written in November 1977, provided in connection with this study by reference 2, and pertinent today:

- ...approximately 3200 ship movements alongside Pearl Harbor facilities each year...average condition of fender systems is fair to poor... primary problem has been insufficient recognition of recurring nature of waterfront maintenance...relegated to irregular funding of large projects and contract accomplishment...waterfront will always be in fair to poor condition.

• More viable approach...recurring maintenance...requirement totals $955 K/year...large enough to keep full-time wharf crew busy.

• In addition...$7 million in unfunded repairs, both fender and structural, should be funded and accomplished by contract.

k. Naval Station, Rota, Spain

• Annual maintenance of fender systems is virtually nil...most damage of major scope...result of wear, abrasion, collision or other contact with ships and camels...all repairs by contract.

• Marginal wharf...hung timber fender with rubber blocks in compression. Replaced system in 1970...second repairs imminent at $90K...most damage by ships and camels.

• Finger pier...timber pile system with rubber blocks...repaired in 1964, 1967, and 1979. Latest work replaces timber piles with steel... damage by marine borers and abrasion/collision.

• Fuel pier...originally timber pile system...inadequate for type and number of ships...replaced in 1964 with 26 steel pile clusters...miscellaneous repairs in 1970, 1973, 1976, 1977, 1978 at total cost of over $300K. 1979 repairs will sheath clusters with wood and add 12 low pressure pneumatic fenders.

l. Naval Amphibious Base, Coronado, CA

This activity was not included in the mail survey because it berths no ships. Due to the input from NAB, Little Creek on fender system problems in the Beach Group/ACB area, telephone input was obtained from Coronado.

The facilities planner expressed great interest in the survey and invited CEL representatives to visit Coronado. He described a continuing and major problem of damage to timber pile fender systems, naming MIKE boats as the major cause. PWC San Diego performs recurring maintenance and keeps a stock of fender piles at NAB. In addition, the activity has a backlog of 21 Special Projects totaling over $1 million for pier repairs.

2.1.2 Activity Cost Data. The mail survey requested maintenance and repair (M&F) cost data with full recognition of the variance in naval activity cost recording and with an understanding that obtaining costs on specific parts of facilities is always difficult and often unfeasible. The result displayed in table 1 is about as expected. There is one characteristic of the historical costs that can be relied upon. Only known incurred costs were reported; no estimates of additional expenditures were included, so the M&R historical figures are conservative. On the other hand, future (backlog) estimates could be liberal, but due to inflation are usually met or exceeded by the time funds are available for execution.

TABLE 1. FENDER SYSTEM MAINTENANCE AND REPAIR COSTS

ACTIVITY	MAINTENANCE ($000) FY-76	77	78	79	Backlog	REPAIR ($000) FY-76	77	78	79	80	81-?	
SUBASE New London	10	10	10		300				141	15		
NSY, PHILA			37					98	88	388	1,954	
NWS, YORKTOWN							306			310		No routine maintenance; contract repairs on 3 year cycle.
NAVSTA, NORFOLK	243	262	354	800			18	295	151		332	
NAVBASE, CHARLESTON	139	169	108		1,270							
NAVSTA, MAYPORT						202	453		280		300	
NSY, LONG BEACH	43*	123	104	78*		520	25	1,875	1,025			*Partial. OPN request for camels= $980K.
NSY, MARE ISLAND		261	2,000		1,600	73	56	28		413	808	Repairs FY-76 - 78 exclude work by contract.
NSY, PEARL	207	147	121		96				220	240		
NSC, PEARL	10	172	248		157				201			
NAVSTA, PEARL												$400K/year per PWC estimate in 1977.
SUBASE, PEARL												$157/year per PWC estimate in 1977.
NAVBASE, SUBIC BAY	116	233	190		78				912*		3,081	*Previous 5 year repair costs.
NAB, LITTLE CREEK									934* 1,438	120	276	*Fender systems only. Includes other pier repairs.

2.1.3 Ship Damage Data. With the exception of the NAVSTA Norfolk ADHOC Committee Study, very little data was submitted on specific damage by ships. Activities tend not to obtain or record this data; it is more often considered 'business as usual' similar to potholes in roads. However, all activities, except the Shipyards at Philadelphia and Mare Island, stressed the extent and constancy of damage caused by ships. In the minds of all those contacted, it is THE fendering problem.

Those few incidents reported are summarized as follows:

a. LHA

Lack of adequate bulk camels. Storm, moderate sea and wind. 20 fender/11 bearing piles; $160K.

b. CV

Tug support.

26 fender piles sheared by camel; $22K.

c. Tug

14 fender piles and complete system; $13K.

d. DD

Wind

Damage to hung fender; $15K.

e. Ammo Ship

Wind

Damage to hung system; $8K.

The Norfolk study provides good insight into and the only source of comprehensive data on, this problem. It is, therefore, quoted at length in this paragraph.

"FENDER PILE DAMAGE STUDY

The largest single study conducted by this committee was the cataloging of fender pile damage. A Naval Station officer personally walked piers, observing damage and causes at least three times a week for 28 weeks between May and November 1978. Whenever possible he concentrated his observations at times and locations when ship movements were occurring. The original study encompassed four piers; two which normally berth large ships, #5 and #7, and two which normally berth small ships, #20 and #21. At the fifteenth week a fifth pier, #25, was added to the study. Pier #25 was added because it had an energy absorbing fender

system and it was thought that this pier might have yielded significantly different data; it did not.

The committee has studied the data collected during this 28 week period and finds that few conclusions can be drawn. There are many factors which contribute to fender pile damage; however, there seem to be two major contributors which can be singled out: camels and ship handling/tug operations. Appendix A is a compilation of the damage study data. The single piece of information that stands out in this data is that the probability of damage increased dramatically when camels were used.

The higher than normal damage rate when camels are used was not totally unexpected. Camels, especially those relatively short ones (usually 30 feet in length) normally used with smaller ship types, tend to concentrate the load on a few fender piles. The data confirms that damage rates increase with camel usage. Comparing the percentage of ships using camels to the percentage of damage involving camels (appendix A) will demonstrate this dependence.

Ship handling, especially when camels are used, seems to be a relatively important factor in damage rate. The committee believes that factor is essentially beyond control of the Naval Station because of the large numbers of personnel involved and inability to hold an individual operator fiscally responsible for damage. In the commercial world this fiscal responsibility of operators does seem to have a positive effect on controlling fender system damage.

One historically important cause of damage did not occur during our study period. This cause was a major storm.

The major conclusion from this portion of the study was that limiting camel usage should be pursued.

CAMEL USE STUDY

Because of the many discussions surrounding camel usage, the Naval Station Port Services Department collected data for a one month period on camel usage. This data is summarized in appendix B. The result of this study is a confirmation of the conventional wisdom that most ships use camels to prevent damage to ship sides such as marring of paint. The conclusion can then be drawn that significant portion of camel usage could be curtailed and that rubber fenders could be used instead."

2.1.4 Engineering Field Division Input

a. Atlantic Division (Design Division)

- Two recently constructed piers were designed with energy absorbing systems similar to DM-25-2-7, figure 2-6 (b)...indications are that its damage will equal that of the standard timber system.

From the Norfolk ADHOC Committee Study:

APPENDIX A

FENDER PILE DAMAGE DATA

CAUSE	PIER 5	PIER 7	PIER 20	PIER 21	PIER 25
	NUMBER OF PILES DAMAGED				
Ship handling - camels in use	23	23	16	14	8
Line handling/weather - camels in use	5	13	7	6	5
Total - camels in use	28	36	23	20	13
All causes - camels not used	12	5	3	0	0
Total	40	41	26	20	13
Percentage of damage involving camels	70%	89%	88%	100%	100%
Camel usage by ship pierside	59%	64%	39%	50%	84%

Note: Piers 5 and 7 are used primarily for large ships such as: CVA, LHA, LPH, LCC, AO, AOR, LRA, LPD, and LSD. Piers 20, 21, and 25 are used primarily for smaller ships such as: DD, DDG, FFG, and FF.

APPENDIX B

CAMEL USAGE DATA

For ships arriving 29 Jan 79 to 28 Feb 79

REASON FOR CAMEL USAGE	NUMBER OF SHIPS QUERIED	PERCENTAGE OF THOSE USING CAMELS
1. Keep from damaging ship side	12	63%
2. Ship configuration problem-ships such as CVA or LPH	3	16%
3. Other operational reasons	4	21%
4. Did not use camels	4	

- Well known that standard system can absorb limited energy...concluded that a majority of systems are under-designed for impact. Two energy systems designed for impact but not for camels.

- Camels of adequate length seldom used/available. Increasing the size and number of piles has worked well on carrier piers but is too costly where random berthing is used. Any future piers, because of experience, will likely be designed with a standard driven timber pile system.

- Camels cause largest amount of damage...tugs second. Ships out of control cause major damage but infrequent and not a large contributor. Biological damage is not significant at busy port...overload damage occurs first.

b. <u>Northern Division</u>

- Present technology for submarine fendering is limited...standard deep draft camel too costly in maintenance and downtime...new design not tried...experimental design will be tried.

- Maintenance problems stem from overload, biological damage, abrasion, chemical deterioration of concrete/steel, failure of connectors/welds, destruction of energy absorbing units.

- Failure when kinetic energy of ship is not properly absorbed... attributable to poor design.

- A low maintenance system is needed even if initial cost is high. A quantitative testing series is needed to define physical characteristics of various energy absorbing devices.

In addition to these comments, NORTHNAVFAC provided a write-up and cost estimate for the test section hydro-elastic fender proposed for SUBASE New London. This system is addressed in paragraph 3.2.1 and the NORTHNAVFAC input is contained in appendix D.

c. <u>Pacific Division.</u> PACDIV submitted six volumes of the Waterfront Berthing Facility Survey covering Hawaii, Midway, Guam, Okinawa, Phillippines, Sasebo and Yokosuka, Japan. These surveys were conducted in 1977-78 and provide a very comprehensive report of the condition of facilities at that time and the Special Projects in the backlog. The surveys, of course, were not particularly concerned with causes of damage or deterioration nor with the potential for design changes. The information on fender systems is, therefore, restricted to brief statements of type and overall condition. In most cases, the cost estimates for repair backlogs and Special Projects do not separate fender systems, but include fender repairs with other waterfront work.

The general picture portrayed by the surveys is typical. The great majority of fender systems are timber pile or hung timber systems. Both are continually being damaged by berthing forces and require constant maintenance and

periodic replacement by major project funding. Exceptions to the standard timber systems noted are:

- In Guam, the replacement of fenders destroyed by storm on berths with solid concrete faces was utilizing rubber 'port slide' bumbers for all activities. Also, Bravo Wharf utilizes 10" O.D. rubber bumpers in conjunction with the timber pile system.

- In Subic Bay, existing timber fenders were being considered for replacement with a steel pile, steel wale, rubber unit system due to the success of such a system in use on Leyte Wharf. The cost for such a change on Alva Wharf was $3.9 million. A similar project for the Supply Pier was being considered at $2.5 million. It is interesting to note that the PACDIV survey refers to repair projects for this change in design which is contrary to comments from certain activities received in this survey.

2.2 ON-SITE SURVEYS

A principle source of information on the current fender system situation was on-site visits to the naval activities in San Diego, CA., and Norfolk, VA. Approximately 234 ships are homeported at these two complexes; 102 at Naval Station, San Diego and NAS North Island; 17 at NSSF, Point Loma; 88 at Naval Station, Norfolk; and 27 at NAB, Little Creek. A complete cross-section of berthing problems was observed.

The most important input gained from the visits was generated from the knowledge, experience and opinions of the operational and maintenance personnel who deal with the ship berthing and fendering problems on a day-to-day basis. As was expected from prior conversation and written input to the mail survey, there is an overall concern that fendering is costing too much in dollars and effort and improvements are needed in design, materials and equipment - with variations on emphasis by location. The Naval Station, Norfolk, ADHOC Committee study accomplished during the period March 1978 to May 1979 is a reflection of this concern.

The following paragraphs discuss the visits. The names of personnel contacted are listed in appendix C.

2.2.1 On-Site Survey - San Diego, California. During the period 31 July - 2 August, an on-site survey was made of fender systems at the Naval Station, Naval Air Station, North Island, and the Submarine Support Facility, Point Loma. The coordinator for these visits was the CEL representative at the Public Works Center. The most significant item revealed in the San Diego survey is the change in fender design that is being implemented or recommended by PWC for all activities. As opportunities arise, the conventional timber pile - timber waler fender system is being revised to incorporate 18" vice 14" piles at closer spacing, 12" to 24" O.D. rubber fenders between the top waler and the pier, and heavier waler construction. The changes are essentially transiting the San Diego area fender systems from the temporary category to the semipermanent category.

a. Submarine Support Facility, San Diego (NSSF). Discussions were held with the Commanding Officer, who also conducted a tour of the piers. The information received here and from PWC personnel emphasized the above mentioned design changes and credited them with solving the fender problem at NSSF. It was estimated that Pier 5000 was requiring replacement of 150-200 piles a year until recommendations contained in the Blaylock-Willis and Associates Fender System Investigation, Pier 5000 (appendix D), were implemented. These recommendations were:

1. Docking velocities be minimized as much as possible. This is of primary importance.

2. Resilient rubber bumpers be substituted for the solid rubber blocks now connecting the wale to the pier.

3. Existing damaged 16-inch piles and existing piles of smaller diameter be replaced with new 18-inch butt diameter members.

4. Rubbing strips be installed on all piling.

5. Care be taken with the replacement piles to insure their being placed in line and parallel to the pier, and

6. Undamaged deep draft camels with minimum lengths of 50-feet be used exclusively during docking activities.

As mentioned in the A&E investigation and by the personnel visited, berthing of submarines is complicated by the tidal velocity at NSSF. A low velocity approach is very difficult when the tide is running. After two years of service, no damage has been experienced at Pier 5000 and no maintenance funds have been required. As a result of this experience, repair Special Projects are being funded to upgrade other berths. As an example, Project R1-78 for Pier 5003 is estimated to cost $375,000 and calls for 18" piles on four-foot centers and 24" O.D. cylindrical rubber shock absorbers on 16' centers. It is believed that improved alignment of fender piles contributes to the success of the revised system, but there is no way to substantiate this.

b. Naval Air Station, North Island. Brief discussions were held with the Staff Civil Engineer and a tour was taken of Piers J/K, the aircraft carrier quaywall and the ammunition pier now under construction. The quaywall is not really within the context of this study since the only attached fendering is vertical concrete bumpers - totally rigid - that, due to the integral construction, are part of the quaywall. Pier J/K has a conventional timber pile-waler fender system. A large variety of ships are berthed with little mechanical damage to the pier fenders. The personnel available knew of no particular reasons for the lack of damage. It is believed that the wind-sea-current conditions allow low velocity approaches and that the use of camels is infrequent, both of which significantly reduce incidents of damage.

The new ammunition pier has not been put into service. The fender system is composed of 18" piles on about 8' centers, a heavy double waler system, and

24" O.D. cylindrical rubber fenders between the system and the pier. It appears massive enough to give good service. In fact, this fender system is constructed in areas where access and water depth restrict berths to small craft.

c. Naval Station, San Diego. Discussions were held with the Staff Civil Engineer and his assistant, personnel of the Waterfront Operations Department, and planning-engineering-shops personnel of PWC. A tour of certain piers was also made. The Naval Station is in the middle of a multi-year program to upgrade some piers, to totally replace certain piers, to improve pier utilities, and to replace fender systems. Both Military Construction Projects and Special Projects are being utilized. As a result, fender systems on complete piers are being replaced by contract. This program makes an analysis of annual maintenance cost inapplicable, but in conversation it was estimated that $250K - $300K was being expended from local O&MN funds prior to the MILCON/Special Project program as compared with a rate of $75K per year currently for maintenance performed by PWC.

The Waterfront Operations personnel provided a good synopsis of berthing conditions (5'-7' tide, wind conditions, etc.) berthing procedures and problems, and the effect of using camels. The concensus was that significant damage is caused only by extenuating circumstances such as storms, high winds, or when small combatants berth unassisted by tugs. Emphasis was given to the berthing problems, and fender damage, caused by LHA's and LPD's. These ships require camels and the berthing load frequently breaks fender piles due to uneven distribution at initial impact. An accident involving LHA-1 was a subject in the NAVSTA discussions due to the damage caused not only to fendering but to the pier and a collimation tower. This type of incident is not too pertinent to this study, though, since it does not seem practical to construct general purpose fendering to withstand such major accidents.

One item discussed by the Staff Civil Engineer applicable to all activities in San Diego was the quality of materials used in repair-replacement of fender systems. Due to the contrast noted between the excellent materials used by contractors and the relatively poor materials procured by PWC, a study of materials available, procurement procedures, and the specifications used for purchase was made by PWC in conjunction with the Civil Engineer Support Office. The results were revisions to the specifications and an overall improvement in materials procured. This item has possible application to other naval shore activities.

The Naval Station makes extensive use of large log camels chained to the fender system and credits these camels with a significant reduction in pile damage. The camels are expensive due to the diameter and length required, and create problems such as erosion of the pile face by rubbing action and breaking chains, but the people involved consider the advantage far outweighs the disadvantages. The benefit, of course is simply the spreading of berthing loads over a larger number of fender piles.

Miscellaneous comments by PWC personnel concerning the Naval Station included:

-a specific disagreement with the fender bolt design for the new Pier 2. It was recommended that the comments be provided to WESTNAVFACENGCOM prior to start of construction.

-the addition of metal rubbing strips on fender piles subject to constant erosion by camels was recommended. The economics of this addition are questionable.

-one office in PWC estimated annual fender system maintenance costs of $700K for the San Diego complex with approximately 15% of the piles being replaced each year. In view of the extensive project program at the Naval Station and implementation of the new design at NSSF, these figures are probably history - not applicable today or in the future.

Conclusions reached pertaining to the Naval Station are:

(1) The overall condition of fender systems is good primarily due to the project program underway but also due to apparently excellent work performed by PWC using quality equipment and materials. Piers in poor condition are deliberately not being maintained because upcoming projects will replace the fender systems.

(2) Other than contingencies such as storms, accidents when ships berth unassisted, and tug error during assisted berthings, the factors contributing to fender damage are those expected and relatively mild; wind action on berthed ships and concentrated loads in initial impact caused by short camels.

d. Degaussing Station. A survey was made of the main pier in use. The pier is protected by dolphins and ships using the facility are berthed with care as a matter of course. The facility has no fendering problems as such, the problem being one of overall deterioration and environmental damage to all piling. No significant mechanical damage is experienced and no changes to fendering design could be recommended.

e. Naval Supply Center Fuel Terminal. This large T-shaped pier incorporates a standard timber fender system which sustains continuing, significant damage from berthing ships. It was reported that $150K a year was spent on maintaining the fender system for this one pier. PWC has recommended the submission of a project to replace the fenders with a design similar to that used at NSSF and on the North Island ammunition pier - larger piles and resilient rubber fenders.

Overall conclusions concerning San Diego include the following:

a. There is not sufficient data available on costs, extent of miscellaneous damage or repair and replacement work performed to substantiate the

economics of the change in design, the use of log camels, recurring maintenance versus periodic total replacement by Special Project and the like. The lack of data does not, however, negate conclusions drawn from long experience by the people involved such as the overall benefit of long log camels the operational necessity of continuing repair by PWC, and the cost benefit of the heavier fender system being phased in. The cost of fendering ships in San Diego, though, is significant and warrants more formal recordkeeping by PWC and the Naval Station of selected locations, changes, etc. to get a better handle on costs, length of life and effectiveness of changed designs.

b. The use of long, large diameter log camels appears to reduce breakage of fender piles to a substantial degree.

c. The revised fender design incorporating larger size components and large diameter rubber fenders will reduce real costs in the long run. The cost of berths being out-of-service due to damaged fenders and downtime for repairs is an intangible, but real cost that has been reduced at NSSF.

2.2.2 <u>On-Site Survey - Norfolk, Virginia.</u> During the period 20-22 August 1979, an on-site survey was made of fender systems at the Naval Base, Norfolk, the Naval Amphibious Base, Little Creek, and the Norfolk Naval Shipyard, Portsmouth, Virginia. The principal point of contact for the visit was the Maintenance Division of the Atlantic Division, NAVFACENGCOM. Mr. R. Graham provided coordination and liaison, having served as the LANTNAVFAC representative on the NAVSTA ADHOC Committee described elsewhere in this report. A synopsis and discussion of the survey follows:

a. <u>NAVBASE, Norfolk.</u> Discussions were held with the Naval Station Staff Civil Engineer, the former Berthing Officer, and Public Works Center (PWC) personnel. In addition, a walking tour was made of several piers and a small boat tour was made viewing the fender systems and berthing practices from water level.

The fender systems are conventional timber pile, timber waler design throughout. The newer piers, #24 and #25, were constructed with similar systems, differing only by the addition of 12" O.D. rubber fenders attached to the pier with metal straps behind the top waler. There are no design practices here that can contribute to improvements elsewhere.

The fenders are repaired/maintained primarily by PWC funded from annual O&MN funds by the Naval Station. Repairs by contract using Special Project funds is a minor source. Current NAVSTA funding is approximately $800,000 a year with a predicted increase to $1 million in FY 80. The only apparent local change to the fender systems in recent years is in the spacing piles. Through local PWC-Berthing Office agreement, double piles have been driven in certain high impact areas. The cost-benefit comparison of this practice is questionable due mainly to the quality of piles being used and the alighment obtained. The round rubber fenders incorporated in the newer piers are being eliminated as sections of fender systems are destroyed and replaced. For unexplained reasons, PWC personnel consider the rubber fenders to be ineffective and a part of the problem rather than an improvement.

The overall condition of fender systems is poor. Almost every berthing space observed has a significant section of fendering missing or severely damaged. The backlog of repair work is high and, according to PWC, is increasing. The impression received from inspection of the piers is that: (1) mechanical damage is exceeding repair efforts; (2) the ships are living with a slowly increasing number of missing or broken fender piles; (3) maintenance funding is not the primary problem; and (4) within 2-3 years major repair efforts accomplished by contract with Special Project funds will be necessary.

Factors contributing to mechanical damage raised in discussions were:

-the effect of using camels which is discussed in detail in paragraph 2.1.3.

-wind and sea action on berthed ships, including the wave action created by vessels passing in the channel.

-the elasticity of nylon lines that allows ship movement away from and against camels/piers.

The comment was made that commercial piers experience less damage because, among other reasons, they use automatic line tensioners and do not use camels. No significant amount of damage was attributed to tug handling problems or to unassisted berthings.

Problem areas derived during this visit that are not discussed in reference 1 include:

(1) Materials. The southern pine fender piles being used are inferior and unsuitable for an effective fender system. The size of piles vary greatly; some as small as 9"-10" butt, ranging to the 14" size designed. The variance in size contributes to the alignment problem and, therefore, to the number of piles resisting a given load. Untreated piles are used in high impact areas, which is appropriate due to the frequent replacement required.

(2) Equipment. The pile driving equipment available at PWC is old and unreliable. Downtime is a constant problem. The equipment used undoubtedly contributes to the alignment problem, and productivity is decreased since the YD must have tug assistance to move.

(3) Access to damaged areas is a constraint on PWC which decreases productivity and increases cost. They reportedly average 5 piles a day unless driving double piles in an area.

(4) The accumulation of residual fender pile stumps at many piers is becoming a problem and under present practices can only escalate. It was reported that in one excavation, ten feet in diameter, 16 pile stumps were encountered.

Conclusions reached concerning the fendering problems at NAVBASE, Norfolk are:

(1) As concluded by the ADHOC Committee study, camels are a significant contributing factor. Along with efforts to better control the use of camels and to obtain funds for longer replacement camels, the use of log camels should be thoroughly investigated and a few purchased and tried in high impact/damage areas.

(2) The timber piles used are not effective. A comprehensive investigation of pile procurement, specifications used, and inspection performed should be made to optimize the materials now being purchased. As a longer range item, a cost comparison of the use of Douglas fir piles of larger diameter should be made. This item would be a part of an overall review of fendering practices in Norfolk.

(3) Funding and the availability of repair expertise/labor are not parts of the problem. The design utilized, the quality of piling procured, the damage caused by inappropriate use of short camels, and the inefficiency of the equipment, scheduling and restricted access for maintenance combine to create the NAVBASE fendering problem.

(4) Present maintenance capability, practices and materials, in effect, produce a temporary category fender system. The fenders are serving the basic purpose of protecting the piers, but at a high cost in dollars and out-of-service fender systems. The money spent on the fendering function is probably very close to, and may even exceed the cost of providing a semi-permanent category system with far less inventory out-of-service at any point in time.

(5) It appears that expenditures of $800K to $1 million a year will not decrease the repair backlog. Since improvements such as better materials, new pile driving equipment, better camels and the like are relatively long range, it is appropriate to program major repair Special Projects for fender systems incremented, say, during the FY82-84 time frame.

b. NAB, Little Creek. A brief discussion was held with the Public Works Engineering Division Director, a port pilot and the docking master (berthing officer equivalent), and a tour was made of some of the piers and berthing areas. The fender design at Little Creek is the same as the Naval Base. No recurring maintenance is accomplished. The activity has eliminated the in-house capability to replace pile fender systems and relies totally on Special Project funding with contract accomplishment. During the visit, renewal of the fender systems was in progress, consequently, much of the inventory is new.

Again here, the consensus of the activity is that camels are the major problem. Many of the amphibious ships must use camels and most of those available are short and concentrate the load on a few fender piles. It was reported that new, longer camels were being procured. The allied major factor contributing to fender pile damage is movement of berthed ships caused by wind action.

The major piers are oriented east and west and the prevailing winds are from the north or south. The ships berthed have large surface areas subject to wind forces and movement to and from the pier is significant.

The port pilot's recommended solution is to drive 5-pile clusters approximately 20' apart at berths that consistently require camels. These small dolphins would accept the load from camels and absorb the impact of ship movements. This would, in effect, be providing a semi-permanent category fender system for those berths. The size of the pile clusters would be a matter of design, but for the Amphibious Base situation it appears to be an excellent suggestion. It would, also, provide protection for another item of concern expressed; i.e., the utility lines located just behind the fender piles that are subject to rupture. Both fuel and sewage lines were mentioned.

The Desert Cove berthing area is atypical to this study, but has similar fender system damage problems. The area is used to berth small craft and causeway sections used by the Amphibious Construction Battalion. Mechanical damage is significant and constant. It was mentioned that CEL performed a specific study of Desert Cove fendering, circa 1977, which offered three potential solutions - all too expensive to implement.

During this visit, berthing of the PHA-1, USS PEGASUS, was observed and is discussed elsewhere.

Conclusions reached concerning NAB, Little Creek, are:

(1) Mechanical damage to fender systems, while probably not as severe or as frequent as at the Naval Base, can be reduced by improvements to camels used and to fender system design.

(2) The suggestion for using small dolphins for specific berths should be seriously investigated. All things being equal, a trial installation at one berth seems warranted.

(3) Based upon the result of an investigation by the Naval Base, similar consideration should be given to the economics and a trial of log camels.

(4) The activity, in conjunction with LANTNAVFAC and CINCLANTFLT, should address the fendering problem in depth prior to executing the next cycle of major repairs through Special Project funding. It appears that, in collaboration with CEL and the EFD, improvements over the present design can be effected within current life-cycle costs.

c. <u>Norfolk Naval Shipyard</u>. The visit to the shipyard provided nothing of value to this survey. There are no fendering problems at this activity for a variety of reasons, including:

(1) Most of the berths are along quaywalls or solid faced concrete piers which take the impact load directly.

(2) Ships are all berthed with tug assistance, remain at berths a longer period of time, and are under the control of the shipyard.

(3) The berths are protected, little sea or wind action to contend with, and the use of camels is more judicious.

2.3 REVIEW OF PREVIOUS STUDIES

Two basic purposes in mind during this review were:

- To identify areas bearing on the problem that have been fully investigated and that are not subject to significant change; to benefit from the surveys of fenders in use that have been made.
- To draw comparisons between findings and practices at different points in time. Changes in design of fenders and apparent results of those changes are of interest. The relative cost of maintaining fender systems, factors contributing to damage and recommended corrective actions, tried or rejected, are of value in evaluating the problem.

The following provide synopses of the pertinent contents/points of the applicable documents.

a. Technical and Economic Analyses of Fixed Fender Systems at Ten U.S. Naval Stations, T. T. Lee, 1965-66 (unpublished NCEL technical report).

The purposes of this study, similar to the current effort, were to identify the magnitude and causes of fender system problems, to judge the extent and commonality of problems Navy-wide, and to determine potential solutions that might be achieved through joint research, design, maintenance and operational effort. Surveys of ten activities were conducted and pertinent local recommendations were made for each site. The overall conclusions were:

- problems at different activities varied significantly
- large maintenance costs justified further investigation
- lack of documentation prohibited cost-effectiveness analyses
- accidental damage can be reduced by operational means

The study recommendations were:

- local efforts to improve design
- keep better cost records
- document pile length of life service
- future R&D efforts should concentrate on design criteria as related to cost and effectiveness

b. Report on Effective Fender Systems in European Countries, Resselada and Van Lookeren Campagne, 1964, and NCEL Technical Report R376, 1965.

This report and the CEL review were a part of the mid-sixties effort to determine the most effective direction to take in fender systems for Navy piers. They provide good background material on various fender systems in use in Europe, design criteria related to port conditions, and relative costs.

Comment: This material is historically useful after a direction for any future RDT&E effort has been determined, but provides little toward that decision.

c. Improved Fender Systems for Shallow and Deep Draft Berths. Phase I, Dravo Van Houten, Inc. for the Maritime Administration, (MARAD) 1978.

This study, a parallel to the current CEL effort, is being accomplished for US commercial ports. Phase I is roughly equivalent to this survey in that it reviews current fender systems and evaluates problems and type of damage. Phase II of the MARAD study is to present proposed solutions and provide guidelines for specifications and design practices, which is roughly equivalent to any follow-on CEL effort.

The Phase I report to MARAD reviews fender systems design, types and typical installations, costs, causes of problems and damage, maintenance and repair of fenders and ship trends. The report is concluded with a ranking analysis of fender system problems related to types of fenders and prevalence of use and a priority assignment of design objectives.

This study was accomplished, in part through a questionnaire to 100 members of the American Association of Port Authorities that received a 50% response.

Comment: This study is an excellent source of comparative information for the CEL study. Results and indications from the Navy survey should be compared with the MARAD study. Conclusions reached that vary significantly should be investigated.

d. Design Criteria for Camels or Floating Fenders, NCEL Technical Report 174, January 1961.

This report researched and reviewed ship berthing forces, design criteria that should be used and recommends development of designs for two particular type camels.

Comment: This report, even though 18 years old, will be useful if the problem of camels contributing to fender damage is pursued in depth.

e. A study of Effective Fender Systems for Navy Piers and Wharves, NCEL Technical Report R-312, 1965.

This report provides description, cost, case history, etc. for: standard pile fender systems, as well as retractable rubber, gravity-type, pneumatic, and hydraulic and hydro-pneumatic systems. Much of the material is useful and current to the present study.

The study recommended prototype installations of three fender systems for testing; timber piles with rubber fender in axial compression, a retractable fender design, and a corner pile-fender system with rubber units in shear. None of the study recommendations were specifically implemented.

f. Final - Concept Study, Replace Pier 2, Naval Station San Diego, Ferver Engineering Co., July 1978.

As part of an evaluation of alternative pier configurations, this study included comparative studies and cost estimates for fendering systems. The types of fenders investigated were:

- timber piling with rubber units
- cantilevered steel fenders
- prestressed concrete piling
- direct contact rubber cylinders

Energy absorbing camels are also briefly discussed.

Life cycle cost estimates were made for timber pile systems, concrete piling and a steel cantilever system under various length of life assumptions. The conventional timber pile system was recommended but for apparently tenuous reasons.

In the cost analyses, the concrete pile system was very competitive with timber piles even though a 7 to 15 year life of the timber system was assumed/predicted.

2.4 RECENT NAVY FENDER SYSTEM DESIGNS

The designs currently being used by the Navy are of interest in this survey. The following summarizes the design criteria and construction parameters developed.

a. <u>Pier 2, San Diego</u>

The Concept Study, reference 8, recommended a timber pile system using 18" Douglas fir piling 4' C-C at the LHA berth and 15" piling 8' C-C elsewhere, with Goodyear 20R equivalent rubber bumpers (reference 9) and 12" X 12" chocks and waler.

Design criteria provided by WESTNAVFAC is:

LHA (39,200 tons) governed.

Approach velocity	-	0.3 ft./sec.
Effective berthing force	-	97.4 Kips
Wind	-	40 knots
Current	-	0.7 knots

b. Pier 25, Norfolk

Douglas fir or southern pine piles on typical 8'-4" centers with 10" X 12" chocks, 12" X 12" waler, and 12" O.D. x 18" long rubber fenders.

Design criteria provided by LANTNAVFAC is:

AO (38,800 tons) governed.

Impact velocity	-	0.25 ft./sec.
Wind	-	77 knots
Current	-	2 knots

Comment: Even though designed for an AO (38,800 tons), the NAVBASE Norfolk ADHOC Study reported four incidents of damage in a three week period involving a CGN (10,150 tons), a CG (7,900 tons) and a DD (7,100 tons). A total of 13 piles were damaged. None of these incidents involved unusual circumstances such as storm, tug operation error, etc.

c. Pier 24, Norfolk

Construction parameters are the same as Pier 25 except for a typical pile spacing of 9'0".

Design criteria used is:

AD (21,600 tons) governed.

Impact velocity	-	0.25 ft./sec.
Wind	-	77 knots
Current	-	2 knots

d. SSN Pier 32, SUBASE New London

The design criteria was based on nuclear submarines currently berthed. Construction was as follows:

- Steel H Piles, HP 14 X 89, 10' centers.
- Piles stiffened with 1" cover plates both sides.
- Resilient fender similar to Goodyear 'W' series wing trapeziodal, 3' -4" long.
- HP 12 X 53 steel waler.
- H piles are faced longitudinally with 26' long rubber similar to Goodyear 8" O.D./4" I.D. wing type.

e. Shipyard, Charleston

Pier M, three years old - steel fender piles with rubber bumpers.

Pier C, completion in 1981 - same as Pier M.

f. Naval Station, Mayport

Pier A - new cellular bulkhead system currently under construction will use a steel and rubber fender system.

SECTION III

DISCUSSION AND ANALYSIS

3.0 GENERAL

The primary purpose of this survey is to assess the potential of an RDT&E effort to improve Navy fender systems rather than to evaluate and critique current practices. The conclusions, though, must address reasons and rationale, the 'if so, why?' and 'if not that, then what?' questions, so the differences are marginal. No study is required to conclude that more careful ship handling will reduce damage to fender systems. The operations on the water side of the pier are, of course, a factor, but since the sole purpose of the shore facilities is to reduce constraints on the operation of the Fleet solutions to public works problems should be sought that do not further constrain the operators.

Similarly, no study is required to conclude that more detailed and greater quantities of cost data are necessary to make comprehensive economic analyses and comparisons for decision making. This is a fact in most every facilities management problem faced. Actions toward improving fenders should not be predicated upon recurring collection of costs in more detail or the keeping of operational records. Such continuing data collection and recording is expensive and justification for using O&M funds for it cannot be shown. One time cost studies of alternatives and ad hoc efforts such as accomplished by NAVBASE, Norfolk are, of course, necessary for decision.

It is useful to this survey to categorize fender systems into three groups based on intended length of life:

- Temporary category - a fender system designed to absorb the impact of normal berthings by incurring damage. By definition, this type of system should have a low first cost and be designed to be replaced with minimal labor and in a short time. An example would be a hung fender, prefabricated in sections, and literally hung on the pier with available equipment.

- Semi-permanent category - a system designed to absorb the impact of many berthings and to withstand environmental deterioration for a period of time in keeping with its cost when compared with the other categories. Again by definition, this category includes the broad range of fender systems between the temporary and permanent categories. An example would be a timber pile system so designed and constructed that it would withstand the forces of ship berthing until environmental deterioration took its toll. In other words, a system where the material's resistance to environmental damage determines length of life, excluding major catastrophes. As can be seen from this survey, there are elements within the Navy that seem to believe the timber pile systems being designed and constructed fall in this category when, in fact, they are much closer to the temporary category.

* Permanent category - a fender system designed to withstand berthing and environmental damage for the long-range, say 20 years or longer, again excluding calamities. A number of these types are described in references 4 and 8. Examples in reference 8 are the prestressed concrete pile system with an estimated life of 30 years and the cantilevered steel system with a life of 25 years. In general, the U.S. Navy has not constructed fenders that fall in this category. The initial cost is high, design/construction is more complex, and repair is consequently more costly. This category is used more often for single ship type piers/berths rather than for general purpose berths that are common throughout most of the Navy ports.

Within the context of this categorization, the question is: which category fender system should be used on which pier/for what type of ship and is there an economically optimum design for the length of life intended?

3.1 OVERALL ASSESSMENT

By any comparative criteria in the arena of maintenance of real property, the current costs in dollars, effort and downtime to maintain and repair port fender systems is large. With few exceptions, the people concerned with waterfront operations and maintenance consider the costs to be too high for the function performed and are convinced there is much room for improvement. Except in cases where recent or on-going project work has replaced total systems, the overall condition of fender systems is poor to fair. In the majority of locations investigated, the maintenance and repair effort is characterized as an effort to 'catch up' as is the case at Long Beach. Those activities that perform no routine maintenance, but rather depend upon periodic major repair projects as does NWS, Yorktown, risk damage to ships and piers between failure and project execution. NAVSTA Norfolk's effort is sized to 'keep up' and yet backlog is apparently increasing, and the condition of fenders at Pearl Harbor is fair to poor across the board.

In most locations, except for major accidents, the fenders are protecting the piers when in good repair, but using that conclusion in isolation begs the question. At what cost in dollars, berth downtime and risk when damaged fenders expose the pier? In Norfolk, for example, the impression received was that the cumulative feet of berthing times the factor of time exposed to damage because of missing/ineffective fenders was increasing perceptibly.

The most depressing information gained from the survey was the contrast between the uniformity of concerns and expressions of the problems from the activity planning/working levels and the lack of uniformity in efforts pointed towards improvements or solutions. People who work in activities on opposite coasts articulate almost identical analyses of the fender problems. In contrast, LANTNAVFAC states that any future piers, because of experience, will likely be designed with standard driven timber pile systems, NORTHNAVFAC proposes a $2000/LF prototype for submarines, and SOUTHNAVFAC is designing steel pile systems for Charleston and dolphins at Mayport. One opinion expressed by a naval officer during the survey was that "there should be a Navy way".

3.2 RECENT DESIGNS/CHANGES

Changes in fender system designs are being effected but, except for San Diego, tend to be in specific, isolated cases with no apparent centralized technical direction. As discussed in paragraph 2.2.1, an evolutionary change to the timber pile system is being implemented in San Diego using larger components, closer pile spacings, and adding rubber energy absorbing units. Other examples of changes include:

- steel pile system with rubber bumpers at Charleston and Subic Bay.
- steel pile dolphins at Mayport.
- the use of pneumatic fenders in Rota.
- new design for CV camels in Long Beach.

The use of relatively small rubber units and double piles in Norfolk are not considered significant changes; in the first case the rubber units are being eliminated in repairs, and the use of double piles is only an attempt to compensate for inadequate materials. The changes at two submarine ports are discussed in a following paragraph.

The difference in timber piles being used in San Diego and Norfolk is striking. As described, an effort to improve materials procured by PWC, San Diego, was successful. The parallel situation should be fully investigated by PWC, Norfolk. Reference 3 contains considerable discussion of various wood piles pertaining to Norfolk. CEL and CESO can likely provide information to assist PWC, Norfolk in such an investigation.

The recent Navy designs listed in paragraph 2.4 elicit the following comments:

- The Pier 2 design in San Diego continues the relatively minor design change being implemented there and has not been proven for the LHA. With careful material quality control, excellent pile alignment, and in combination with camels appropriate for the ship, this change just may provide a semi-permanent fender system where the activity of marine borers becomes the major concern.
- The recent designs in Norfolk are ineffective. With no abnormal circumstances, ships of 20-25% the designed tonnage are wrecking the system.
- Charleston's experience with steel pile systems has led to the conclusion that maintenance costs would be greatly reduced if steel systems were used on all piers. Implied in this conclusion is that life-cycle costs for steel would be less. Both Charleston and Little Creek raise the point that a change in type of fender system, from timber to steel for example, is considered an alteration/new construction, funds for which are far more difficult to obtain than for repair of existing systems. In contrast, PACNAVFAC refers to replacement steel systems being funded as

repair projects. It is believed that the replacement of damaged/deteriorated fenders on existing piers by an improved design with a lower life-cycle cost would be deemed repair within DOD rules. This point should be clarified to all activities.

3.2.1 Submarine Fendering. Paragraphs 2.1.1 and 2.4d contain information concerning the SSN Pier 32 fender system at SUBASE, New London. In addition, the information provided by NORTHNAVFAC concerning the proposed hydro-elastic system is included in appendix D. Paragraph 2.2.1a discusses the changes made in the timber pile system at NSSF, San Diego, and the apparent success of the fenders now in use.

The Commanding Officer, NSSF, related that the conditions at New London and Point Loma create very similar berthing problems; basically that approach velocities are difficult to control under certain conditions and impact forces on fenders can be significant. In any case, the same type submarines are being berthed while the approaches to solving the fendering problem are vastly different. The cost of the replacement timber system at Point Loma is $375/LF, the cost of the steel H pile system at New London was $850/LF, and the estimated cost of the prototype hydro-elastic system is $2000/LF. Apparently, coordinated analysis and a comparative cost-benefit study is in order, which would also have application at activities berthing submarines not covered by this survey.

For purposes of reference in one document, the engineering study that generated the changes at NSSF, San Diego, is also included in appendix D.

3.3 DAMAGE/DETERIORATION

It is no surprise to find that damage caused by ships is the overriding concern to those responsible for fender systems. At the present time, concern for environmental/biological deterioration runs a distant second. The intensity of concern over the magnitude and constancy of ship damage and the resulting short length of life of timber pile systems is surprising and not generally appreciated above the activity level.

As mentioned in paragraph 3.0, this report rejects enforcement of more careful and restricted ship handling as a solution to fender problems. A continuing dialogue between the ships and waterfront operation/maintenance personnel is of benefit. Each need to understand and appreciate the other's problems. Also, having the shore activity publicize the cost of maintenance and repair of fender systems, without the connotation of finger-pointing, may increase afloat command awareness of the magnitude of the problem. Each side has a common superior, and increased pier maintenance costs are, after all, reducing funds available for operations.

An intertwining thread throughout this survey is the role of camels in fender system damage or protection. In some locations - Norfolk, Little Creek, Mayport - camels were mentioned as a significant cause of damage. Other activities - NAVSTA San Diego, Long Beach - credit the use of log camels with preventing damage. The economics of using long log camels at more locations should be explored. Also, it seems apparent that specific, centralized work on coordinated camel/fender designs for CV's/LHA's and submarines

would be of benefit. This comment is made in the face of hearing more than once that the energy absorbing camel design proposed (in the past) was too expensive to implement.

As stated, the overall concern for biological deterioration is secondary at the present time. With the implementation of pollution abatement measures, the harbor waters are becoming cleaner and marine life more active. As emphasized by Long Beach, life expectancy as a factor of biological attack is decreasing rapidly in certain areas. Any efforts to improve fender systems as a counter to mechanical damage must take this factor into consideration.

In this regard, CEL has found that the mechanical properties of wood piles are reduced by preservation treatments. CEL Technical Note TN no. N-1535 of November 1978 presents the result of tests on Douglas fir and southern pine piles and documents the reduction in flexural properties and compressive strength caused by chemical treatment. Accordingly, Military Specification MIL-P-23613 for pressure treated marine piles warns that dual treatment or heavy salt impregnation may produce "brittle" piles.

There were few unique causes of damage surfaced by the survey. The Amphibious Bases at Little Creek and Coronado have a unique situation at the piers serving the causeway sections and small craft. The damage to fenders is typical, but the type of craft may render any improvements unique in design. Also, Yorktown and NSC, Pearl mention damage caused by barges and miscellaneous ships. Solutions applicable to the Amphibious Bases may well apply to berthing of ammunition and other type barges.

The number of survey inputs relating ship damage to length of life of timber fender systems is noteworthy and is addressed in the following paragraph.

3.3.1 Timber Fender Pile Length of Life. The length of life of the typical timber pile fender system is of interest in decisions concerning procurement of untreated versus treated piles, in expenditures to study biological damage when such damage may be incidental, and in comparative economic analyses of alternative types of fender systems and materials. The organizations at Naval Base, Norfolk have agreed that the use of treated piles in impact areas is a waste of money. As an example of an economic analysis, the Concept Study for Pier 2, Naval Station, San Diego, reference 8, uses estimated lengths of life of 7 years for single treated piles and 10 and 15 years for dual-treated piles. While the activities in San Diego have kept no records of pile length of life/replacement, from all evidence of PWC wharf builders' workload, O&MN expenditures and the experience of other naval activities these estimates appear optimistic. On the other hand, the heavier design of 18" piles on 4-foot centers with 24" O.D. rubber units incorporating highly treated or plastic protected piles may last 7-10 years.

To highlight the length of life factor, comments on pile length of life derived from this survey are repeated here.

a. Lee, NCEL, 1965-66 Survey.

Pearl Harbor - "prior to the study, the average life was thought to be 5-7 years. However, significant number of piles were being replaced every 2 years due to damage."

b. NAVSTA, Mayport

"Fender systems have a relatively short service life due to damage and deterioration. Impacts occurring at an oblique angle cause significant damage . . . "Wood pile dolphins have short service life . . . fuel pier . . . demolished in as little as one year. "Fender Systems normally require replacement in 3 to 5 years . . . impact damage and attack by wood borers."

c. NSY, Charleston

"Our timber pile fenders rarely ever remain in place long enough to deteriorate from natural causes. They are broken off beneath water line as ships are berthed . . ."

d. NAVBASE Norfolk

"In high impact areas, mechanical damage is occurring before biological damage becomes significant."

e. Pearl Harbor - PACNAVFAC 1978

"It has been reported . . . average life for fender pile and associated fender structure has been as little as 1-1/2 to 2 years."

f. NAB, Little Creek

"Mechanical damage has generally destroyed the system long before rot or biological attack has affected system integrity."

g. NWS, Yorktown

"We have experienced very little damage from marine borers, basically because the piles are damaged by ships . . . and must be replaced before their useful life ends."

h. LANTNAVFAC DESIGN DIV.

"Biological damage is not significant at a busy port for overload damage occurs first."

3.4 MAINTENANCE AND REPAIR

Obvious points highlighted by the survey:

- In busy ports, the widespread frequent damage of timber piles leads to a constant maintenance/repair workload which requires relatively lengthy access to and outages of berthing areas.

- Periodic major repairs by project funded contracts are required at all ports, but cannot replace day-to-day maintenance in the larger, active ports. Therefore, effective use of funds on fender systems requires reliable, effective equipment, quality materials on hand and astute scheduling of the work crew.

- Certain activities with less tempo perform no routine maintenance, but rely on periodic project funded repairs by contract. This is economically prudent so long as the projects are funded with a frequency that prevents piers being exposed to damage because fender systems are out of service.

- Timber pile fender systems require almost exact pile alignment which, again, requires effective equipment used by skilled people. Poor pile alignment coupled with marginal quality piles assures a high breakage rate even under normal conditions.

A more subtle indication received is that the constant driving of hundreds of replacement fender piles is accepted as an acceptable part of the business of operating ports by many elements in the Navy; similar to the requirement to resurface flexible pavements or to repaint periodically for preservation. The repair of timber fender systems has become 'part of the landscape' to many and the escalating costs, declining quality of available wood products, aging of equipment, and increasing inventory of damaged fenders are evolutionary rather than catastrophic occurrences.

Very little can be derived from the cost data in table 1. The major claimant level is the only practical level from which sufficient cost data could be obtained and then any analysis would have to include the question, "relative to what?". The survey, and CEL interest, has shown that in Norfolk and Pearl Harbor there is intense concern at the activity level over the magnitude of fender costs.

What M&R related trends are indicated? From this survey, only more of the same can be predicted for the overall shore establishment. San Diego believes the heavier design will enable them to get on top of the damage related maintenance problem and allow dollars and effort to go toward environmental protection of systems. Charleston believes steel pile systems is an answer to M&R problems but one that is constrained by high initial costs. It appears that the situation at NAVSTA Norfolk will become critical unless aided by a heavy infusion of Special Project funds.

3.5 PREVIOUS RELATED STUDIES

The 1965 NCEL survey of ten naval activities, reference 3, reached certain conclusions that vary significantly from this report. That large maintenance costs justify further investigation, of course, is still valid and is a basic reason for the current CEL review, but the other overall conclusions do not contribute to this evaluation. To judge the potential of future research efforts, a macro view of Navy fender systems is more useful than a micro view of specific problems at individual activities. The result of this current survey points out the commonality of fendering problems at the majority of activities rather than the specific differences the previous study emphasized. The conclusions that accidental damage can be reduced by operational means and that lack of documentation prohibits cost-effectiveness analyses have been addressed elsewhere in this report.

NCEL Technical Reports 174 (1961) and R-312 (1965) should be reviewed in relation to more specific follow-on work. Their usefulness is in lessons learned in the past; what was recommended versus what was implemented, which ideas and designs provide the seed for future work and which ones are economically impractical.

The report on commercial port fender systems, reference 5, provides no surprises or unexpected conclusions. The fender problems and causes are the same as in the Navy where timber systems are involved. Timber is the predominant type of installation in the study and the study concluded the obvious; e.g., first cost is less, changeover to other systems may not be practical, timber systems have higher annual maintenance costs.

3.6 UNORTHODOX HULLED SHIPS

Neither the time allowed by the deadline for this report nor the information available locally allowed an investigation of fendering problems for unorthodox hulled ships. The current examples are the PHA, hydrofoil, and the 3KSES, surface effect ship. The USS Pegasus, PHA-1, berthed at NAB Little Creek, is using floating, cylindrical foam-filled fenders. When observed, there were five in place (at a reported cost in excess of $2000 each). There are five more PHA's to be delivered. Are the soft fenders the optimum solution? Are they economical considering cost and expected length of life? Similarly, what type of fendering is required by the SES and who will deal with this question prior to delivery of the ship? These questions should be addressed.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

4.0 SUMMARY

This survey results in two basic conclusions:

a. General Purpose Berthing. For the short and mid-range no RDT&E effort is required. Facilities acquisition and management efforts should concentrate on improving current designs, material quality and installation methods for conventional fender pile systems. For the long range, the Navy should begin considering the potential that wood products suitable for general purpose berthing may not be available in the quantity required.

b. Certain Dedicated and Special Use Berthing. Concentrated, centralized RDT&E effort is required in the near time frame for submarine, CV/LHA, miscellaneous craft and unconventional ship fendering.

The following paragraphs discuss these conclusions and provide related recommendations. The recommendations are not restricted to those that may be implemented by CEL.

4.1 GENERAL PURPOSE BERTHING

It is not practical to radically change the fender systems on the large majority of existing piers in the Navy. On the other hand, it is practical to implement a number of improvements to the conventional fender systems that will significantly affect length of life and maintenance and repair costs. Research and development are not required for such improvements, but centralized studies, cost analyses, decisions and technical direction are required. Design practices for new piers and for repairs of existing piers are continuing that are 'blind' to the maintenance of real property facts of life and are perpetuating increasing maintenance costs.

The reasons in support of continuing the conventional fender systems are rather self-evident and include:

- The chances of widespread implementation of a new development within the Navy's funding constraints are slim, while certain improvements can be implemented within the funding level now applied to fenders.

- There is much experience available in construction and maintenance of conventional systems and improvements within current designs would be easy to implement.

- The likelihood of developing a new design for general purpose berthing that would be practical to install on existing piers is low.

- Even if a feasible new development was perfected, the Navy's facilities system contains no factor to ensure its use. It is likely that the conventional fender systems would continue to prevail in both new construction and replacement projects.

The above notwithstanding, the Navy should be looking forward to the potential of wood products suitable for ship fendering becoming too valuable a resource to be expended/consumed in the quantity required. It is very conceivable that the cost/availability factor of wood piles, timbers and log camels could result in a prohibitive constraint while the Navy is still relying upon that material for fendering of most ships.

4.1.1 Recommendations.

1. Make a detailed analysis of the timber pile fender design changes being implemented by PWC, San Diego, and WESTNAVFACENGCOM as represented by Pier 5000, Submarine Support Facility, and the new ammunition pier, NAS North Island, for the purpose of implementing these changes through PWC, Norfolk, LANTNAVFACENGCOM and elsewhere as beneficial. Include the material procurement procedures and pile driving practices of San Diego that result in the use of high quality materials and good pile alignment in this analysis. Implement the changes on at least one pier at NAVSTA Norfolk as a test using maintenance/repair funds programmed.

Publicize the specifics of the design being used and of the material procurement practices in San Diego to all activities using timber pile systems, and to PWC's and EFD's.

2. Fully investigate the cost of using long log camels on the east coast. Try such camels for at least one active general purpose pier in Norfolk. Publicize the current experience of San Diego and Long Beach in the use of log camels, and the result of the test in Norfolk, to activities not now using log camels.

3. Clarify to all activities the rules concerning repair versus new construction/alteration when applied to the replacement of timber fender systems with steel on existing piers.

4. Make a design and cost analysis of the suggestion by NAB Little Creek to use pile clusters at certain dedicated berths to accept the camel bearing load rather than the conventional timber fender pile system. Compare predicted costs and length of life with the current system and within repair funds planned, test the idea on one or more berths. If the results are positive, publicize and implement the idea at other applicable locations.

5. Bring the applicable major claimants fully into this effort and incorporate the tests, and then the resultant decisions, into the next cycle of major repairs funded by Special Projects. Do not execute another cycle of major repairs at activities such as NAB Little Creek, NAVSTA Norfolk or NWS Yorktown using the designs now in place.

6. Initiate an unconstrained 'free thinking' study that asks the questions:

- What is the 20-50 year future of wood products in the U.S. that are required for fendering Navy ships?

- What would the Navy do if the availability and cost factors of such materials prohibited use for fendering ships?

4.2 CERTAIN DEDICATED AND SPECIAL USE BERTHING

It is practical to develop new camel-fender system designs/materials for selected critical berthing situations by focusing diverse, uncoordinated efforts into one Navy effort. Considering the amount of money now being spent on repair and maintenance of fenders and repair, construction and procurement of camels appears certain that new designs/different materials could be implemented within current funding levels of O&MN/OPN. The following discusses four areas where RDT&E type work would be beneficial.

a. Submarine Fendering. SUBSUPPFAC San Diego is installing a replacement timber pile system on all piers berthing submarines at a cost of $350/LF. All concerned are convinced the change will solve the fendering problems and drastically reduce annual maintenance costs. SUBASE New London has a relatively new steel pile system, cost $850/LF, and a 90' prototype system is planned at a cost of $2000/LF. These very different approaches are being applied to identical fendering problems. This survey did not cover the activities at Bangor, Washington, and King's Bay Georgia, but the fendering problems fall into this same category. There is a need for a centralized, one Navy, approach to fendering submarines.

b. CV and LHA Fendering. The survey surfaced a number of comments concerning the problems of fendering these class ships. At NAVSTA San Diego, the LHA was considered THE berthing problem. At Pearl Harbor, a CV camel sheared 22 fender piles with the only extenuation being tug support. Long Beach reports an accident involving an LHA during a storm with moderate sea and wind that destroyed 20 fender and 11 bearing piles. Norfolk is driving small pine fender piles at very close spacing to fend off CV's. There appears to be considerable room for improvements to the camel-fender designs. At most locations, berths for these large ships tend to be dedicated.

c. Barges, Causeways, Small Craft. The constant destruction of timber fender systems at Desert Cove, Little Creek, and at NAB Coronado is costing a great deal of money. It would not require much of an improvement in life-cycle costs to effect overall savings. These locations, and other piers serving barges and miscellaneous craft, lend themselves to development of a temporary category system that is low-cost, that can be prefabricated off-site in sections, and that can be installed in a relatively short time.

d. Hydrofoils and Surface Effect Ships. As discussed in paragraph 3.6, the fendering for these ships has not been designed and there is currently no assurance that it will be accomplished in a cost-effective manner. Centralized development of optimum camel-fender designs needs to be accomplished rather than leaving design to the individual locations/organizations that happen to berth such ships.

4.2.1 Recommendations

1. Accomplish a comprehensive and detailed analysis of the in-progress design work and current problems of submarine fender-camel designs encompassing information from all major berthing locations. Evaluate the systems in use and proposed and develop a design or designs that can be procured within economic constraints to serve the newest class submarines. Hold in abeyance construction of the prototype in New London until the initial analysis is completed.

2. Accomplish a similar analysis of CV/LHA fendering practices and in-progress changes in camel design. Develop an optimum design giving consideration to the construction of permanent category systems at dedicated berths.

3. Pursue the development of a temporary category fender that uses low-cost, readily available materials, and that can be prefabricated and installed with normally available equipment for use at the Naval Amphibious Bases and other applicable locations.

4. In conjunction with NAVSEASYSCOM, develop cost-effective camel-fender designs for the PHA and 3KSES class ships.

5. Accomplish these tasks as a centralized effort. Promulgate the results as the approved, Navy technical solution to the specific fendering situation. Require specific approvals for the funding of designs that deviate.

APPENDIX A

STATEMENT OF WORK

FOR

CONTRACT NO. N00123-78-C-0391

The following Statement of Work is in accordance with Section F, paragraph 1.

1. Scope. Conduct a survey of ship fender systems at waterfront facilities at selected Naval shore activities to: identify, document and analyze design and maintenance problems; identify damage by ships related to pier design, location and ship type; collect repair and maintenance cost; and to identify other common and unique fender system problems. Accomplishment entails review of design manuals, studies and other documents for background, on-site investigatory data collection surveys, development of a comprehensive data collection form and a mail survey of certain activities, and preparation of reports as specified.

2. Period of Performance. The work is to begin upon receipt of the tasking document in February 1979 and continue through submission of the final report and consultation in September 1979.

3. On-Site Surveys shall be made at the San Diego Naval complex, Naval Station Long Beach, Naval Shipyard Puget Sound, Bremerton, Washington, and as determined by the sponsor, Naval Base, Pearl Harbor Hawaii.

4. Reports. The findings, conclusions and recommendations shall be provided in a final report not later than 15 August 1979. A draft report shall be submitted for review about mid-July. The report is to provide:

(1) A comprehensive review of the adequacy of current fender systems;

(2) The effects of damage by ships, maintenance/repair costs and downtime, length of life, etc.;

(3) Conclusions concerning an RDT&E project for fender systems.

An original and ten copies are required. Monthly progress reports shall be provided in letter form for the duration of the study.

APPENDIX B

REFERENCES

1. Naval Station, Norfolk - Report of ADHOC Committee on Pier Fender Systems, May 1979.

2. PWC, Pearl Harbor letter 101: FS of 16 August 1978 to CEL.

3. Technical and Economic Analyses of Fixed Fender Systems at Ten U.S. Naval Stations, T.T. Lee, 1965-66 (unpublished NCEL technical report).

4. Report on Effective Fender Systems in European Countries, Resselada and Van Lookeren Campagne, 1964, and NCEL Technical Report R376, 1965.

5. Improved Fender Systems for Shallow and Deep Draft Berths. Phase I, Dravo Van Houten, Inc. for the Maritime Administration, (MARAD) 1978.

6. Design Criteria for Camels or Floating Fenders, NCEL Technical Report 174, January 1961.

7. A Study of Effective Fender Systems for Navy Piers and Wharves, NCEL Technical Report R-312, 1965.

8. Final - Concept Study, Replace Pier 2, Naval Station San Diego, Ferver Engineering Co., July 1978.

9. Goodyear Marine Fender Manual.

APPENDIX C

- Mail Survey Information/Data Forms.

- Naval Activities included in Mail survey.

- Personnel contacted during on-site surveys and points of contact provided by correspondence.

SURVEY OF NAVAL PORT FENDER SYSTEMS

The information requested in this survey will be used to judge the adequacy of current fender systems and to determine the potential of a RDT&E project aimed at improving design, lowering maintenance/repair costs and time and developing new concepts.

1. Evaluate and comment on design of fender systems, dolphins, etc.

<u>SURVEY OF NAVAL PORT FENDER SYSTEMS</u> - con't.

2. Comment on maintenance problems, length of life of materials and the like stemming from design, local conditions, or factors other than damage. Provide maintenance/repair costs on Attachment 1.

3. Provide overall analysis of damage by ships as it pertains to design, maintenance, down-time, etc. Provide examples of ship damage occurrences in the format of Attachment 2.

FENDER SYSTEM REPAIR AND MAINTENANCE COSTS

ACTIVITY: ____________________

PIER/WHARF	YEAR CONSTR.	DESCRIPTION OF FENDER SYSTEM, DOLPHINS, ETC.	ANNUAL MAINTENANCE COSTS				COMPLETED & FUTURE REPAIR PROJECT	
			FY76	FY77	FY78	BACKLOG	FY	COST

NOTES: 1. If costs are not available by pier, provide a total. Estimate if necessary.

2. Include repair projects completed in last 5 years and unfunded projects in the backlog. Show costs for fender systems only.

ATTACHMENT 1

SHIP DAMAGE TO FENDER SYSTEMS

ACTIVITY: ______________________

PIER# ______________

TYPE OF CONSTRUCTION: ____

____

TYPE OF SHIP: ______________

DESCRIPTION OF DAMAGE:

CONTRIBUTING FACTORS:
(Wind, Tug Support, etc.)

COST OF REPAIRS: ________________

Naval Activities Included in Mail Survey

Submarine Base, New London

Naval Shipyard, Philadelphia

Naval Shipyard, Charleston

Naval Shipyard, Norfolk

Naval Shipyard, Long Beach

Naval Shipyard, Mare Island

Naval Shipyard, Puget Sound

Amphibious Base, Little Creek

Naval Station, Norfolk

Naval Station, Mayport

Naval Station, Roosevelt Roads

Naval Station, Rota

Naval Station, Guantanamo Bay

Naval Station, San Diego

Naval Weapons Station, Yorktown

Naval Air Station, Alameda

Naval Air Station, North Island

Submarine Support Facility, San Diego

Public Works Center, Pearl Harbor

Public Works Center, Subic

Public Works Center, Yokosuka

SOUTHNAVFACENGCOM

LANTNAVFACENGCOM

NORTHNAVFACENGCOM

PACNAVFACENGCOM

WESTNAVFACENGCOM

CHESNAVFACENGCOM

Personnel Contacted During On-Site Surveys

PWC, San Diego

Mr. I. Breedlove
Mr. H. Koehler
Mr. J. Jasperson
Mr. J. Deuchars
Mr. E. Brown
Mr. J. Bruce
Mr. J. Squiers - CEL representative

NAVSTA, San Diego

LCDR D. King - Staff Civil Engineer
Mr. J. O'Connor - Asst. SCE
Mr. Warner - Waterfront Ops
Mr. Blair - Degaussing Station

NSSF, Point Loma

CDR. E. Dempsey - Commanding Officer
Ens. Dullum - Asst. SCE

NSC, San Diego

Mr. W. Kalberer - Fuel terminal
LT. Baltikauski - Staff Civil Engineer
Mr. J. Falk - Facilities Planner

NAS, North Island

CDR G. Gardiner - Staff Civil Engineer

Atlantic Division, NAVFAC

Mr. F. Campen - Maintenance Division
Mr. W. Russell - Maintenance Division
Mr. R. Graham - Maintenance Division

NAVSTA, Norfolk

LCDR R. Hoyt - Staff Civil Engineer
LCDR Mercer - Berthing Officer

PWC, Norfolk

Mr. J. Barnes - P&E
Mr. J. Thornton - Waterfront Maintenance

NAB, Little Creek

Mr. W. Niven
- Public Works Dept.
- Port Pilot
- Docking Master

Naval Shipyard, Norfolk

CDR R. Endebrock - Asst. Public Works Officer

Other Points of Contact

Naval Shipyard, Charleston	Mr. V. Svendsen 803-743-3976
PWC, Pearl Harbor	Mr. F. Shiroma 808-471-0065
PACNAVFAC	Mr. J. Moses 808-471-3215
Naval Shipyard, Long Beach	Mr. L. Smith 213-547-6608
NAB, Coronado	Mr. Joe Gorgone 714-437-2436

APPENDIX D

TWO APPROACHES TO SUBMARINE FENDERING

- Proposed Hydro - Elastic Fender System, NORTHNAVFACENGCOM

- Blaylock - Willis and Associates, Fender System Investigation, Pier 5000, Navy Submarine Support Facility, San Diego

PROPOSED HYDRO-ELASTIC FENDER SYSTEM
NORTHNAVFACENGCOM

A hydro-elastic fender system employing a matrix of submerged water jets as an energy dissipating mechanism is proposed for use at submarine pier installations. The energy dissipating device is a rectangular box consisting of a solid front plate installed within a continuous steel grid, compression springs, flexible closures and a perforated back plate installed within a second grid. Steel fender piles top connected to the pier provide lateral and vertical support. The compression springs consist of butyl rubber spacers and are located between the two grids. A preliminary analysis has been made to study the dynamic response of the system to the impact of a nuclear submarine. The results indicate that the introduction of the hydro-elastic element dissipates nearly one half of the berthing kinetic energy and substantially reduces the peak impact force on the piles. Further, the after-impact oscillation of the vessel during the berthing maneuver is reduced. The fender system is relatively economical to install and simple in operation and maintenance.

Fendering systems currently installed at many submarine berthing locations were designed and built at a time when diesel powered boats dominated the fleet. The vessels were smaller, of lesser displacement and much more maneuverable than are the nuclear submarines of recent years. As ship size increased and manueverability decreased, berthing forces became higher and damage to fender systems became a common occurrence. When realistic values are assigned to docking velocities and mass it becomes apparent that the existing systems do not possess the strength of energy dissipating capability needed to counter the berthing forces without damage.

Most of the fendering innovations proposed over the past few decades addressed surface ship application. Lee (1) (2) has reviewed design criteria and fender systems for marine use which ranged from the standard timber piles to hydraulic and hydraulic-pneumatic systems. The configuration of nuclear submarines however, impose some special demands on a fender system. For example, (a) The major beam and therefore its contact with the fender is significantly below the water level, (b) There are sensitive appurtenances at the forward and aft extremes which require protection during berthing and (c) The cylindrical hull form concentrates loads in all but a beam-on approach. To satisfy these special demands floating camels have been developed and are in common use. The more sophisticated provide a high degree of energy dissipation and are effective in distributing forces over a large area. However, floating camels introduce additional operational requirements and reduce manuevering space. Further, they have a tendency to "ride" relative to the pier structure and have a history of relatively high maintenance costs. The hydro-elastic system described herein is considered to be highly suitable for submarine application and combines the inherent advantages of a floating camel with the operational advantages of a fixed fender.

The hydro-elastic fender is an integral unit consisting of the exterior and interior grids, front pressure plate, rear orifice plate and compression springs of resilient rubber elements. The entire system is hung from the fender

piles with above water bolted connections. The design based on a unit 90' -0" long X 30' -0" high constructed of three panels to simplify fabrication.

It is a "softer" system in response to dynamic loadings when compared to other fender pile systems with or without resilient compression springs. The delayed and dissipative response reduces substantially the level of kinetic energy and impulsive force. The system shown schematically in Figure 1, consists of a cushioned steel grid in contact with the submarine, a rectangular energy dissipating "box", compression springs, a rear grid and piles. The solid front plate and the rear perforated plate are incorporated within the grid systems. The box is necessarily located below the low water level so that the submerged water jets can be impulsively activated and discharged into the water behind the piles. To insure an effective dissipation of kinetic energy by these submerged jets, a low porosity of the perforated plate is required. However, an insufficient porosity would result in an undesirable "stiff" system. A proper tuning between the porosity of the plate and the resilient compression spacers is an essential element in design of the dynamical system.

In addition, the flexure characteristics of the grid and pile structures are also coupled with the dynamic response of the energy dissipating box. This is accomplished by varying the flexural properties of the grid until the resulting end conditions are in agreement with the end condition requirements fo the hydrodynamic box. The portion of the energy not dissipated by the submerged jets is absorbed by the remainder of the system as internal strain energy. It is possible to treat the coupled system in its entirety by a generalized single-degree-of-freedom analysis (3).

Exterior and interior grid elements are detailed for construction in 30' -0" X 30' -0" panels and could easily be shop fabricated. The connections are to be fully welded moment resisting connections for the purpose of making a positive closure. The front pressure plate and the back orifice plate are to be bolted for easy removal and installed over flexible spacing washers. The resilient compression spacers shall be held in place with short sections of pipe welded to the grid. The interior connection is plate fastened for convenience.

Short lengths of chain shall be provided at intervals to connect the two grids together. In addition to aiding in erection the chains maintain the integrity of the system should there be a tendency for the exterior grid to move outboard. The wire cables support the entire vertical load of the exterior and are provided with turnbuckles for positioning.

The three 30' -0" panels are to be connected together to provide longitudinal continuity. The connections between the horizontal members of the outer grid should develop the full moment capacity. With the use of floating equipment it is possible to install a full 90' -0" unit without requiring underwater connections. Should operating conditions warrant additional 90' -0" units to be installed, they may be bolted in place. The type of connection is dependent upon the anticipated hit conditions.

Fender piles are required to provide support, both laterally and vertically, for the fender system. Fender piles should be driven to an exact tolerance. If driving tolerances are too great, spacers should be provided to insure the grid will bear reasonably uniformly on the pile system. Connect fender piles to the pier deck using solid timber spacers. Use shims or cut as necessary to make up any variance in pile tops and deck.

The estimated cost of the Hydro-Elastic Fender is approximately $2,000.00 per linear foot. The system is considered economical when compared to other fenders which would satisfy the high energy dissipation requirements. It is to be noted that the effective energy associated with the 1.69 feet per second velocity is over 12 times the energy of a 0.5 feet per second impact velocity commonly used. Measured in cost per foot pound of energy dissipated, the system is highly economical.

30'-0" Section

Material Cost

Steel Fender Piles	18000 lbs	x	$ 0.30	=	$ 5,400.00
Structural Shapes	50000 lbs	x	0.30	=	15,000.
Bolts	750 lbs	x	0.60	=	450.
Pipe	100 lbs	x	0.50	=	50.
Chain	10 lft	x	5.00	=	50.
Turnbuckles	6 ea	x	25.00	=	150.
Clevises	12 ea	x	25.00	=	300.
Timber	2500 bf	x	1.00	=	2,500.
Rubber Elements	24 ea	x	150.00	=	3,600.
Cable	100 lbs	x	0.70	=	70.
	Total Material Cost			=	$ 27,570.00

Fabrication and Erection Cost

Drive 3 Fender Piles	3 ea	x	600.00	=	1,800.00
Cut Structural Shapes	32 pcs	x	50.00	=	1,600.
Pipe	24 pcs	x	40.00	=	960.
Chain	12 pcs	x	20.00	=	240.
Timber	16 pcs	x	30.00	=	480.
Cope Steel Ends	40 end	x	90.00	=	360.
Drill Holes Steel	680 ea	x	5.00	=	3,400.
Timber	130 ea	x	3.00	=	390.
Weld Structural Steel	40 jts	x	150.00	=	6,000.
Chain Rings	12 ea	x	30.00	=	360.
Cable Plates	12 ea	x	40.00	=	480.
Pipe	24 ea	x	20.00	=	480.
Field Drill Holes Steel	12 ea	x	20.00	=	240.
Concrete	6 ea	x	200.00	=	1,200.
Attach Timbers	80 mh	x	20.00	=	1,600.
Attach Rubber Elements	80 mh	x	20.00	=	1,600.
Assemble Inner to Outer	60 mh	x	20.00	=	1,200.
Erect Into Place	40 mh	x	20.00	=	800.
Crane				=	3,000.
Total Fabrication and Erection Cost				=	$ 24,100.00
Total Material Cost					27,570.00
Total In-Place Cost					$ 51,670.00
15% Surcharges					7,750.00
Total System Cost 30'				=	$ 59,420.00
Unit Cost per Foot				=	$ 1,980.67

Extract from a Blaylock-Willis and Associates report of January 1978.

Navy Public Works Center
Naval Station
San Diego, California 92136

Subject: Fender System Investigation, Pier 5000 at Navy Submarine Support Facility, San Diego, CA 92106

ABSTRACT

At the direction of the Navy Public Works Center, an investigation of the fender system of Pier 5000 at the Navy Submarine Support Facility was made. The various aspects of the investigation, the reason for the failures experienced, and the subsequent engineering analysis are described herein. Engineering calculations, computer readout sheets, and construction documents are appended.

It is recommended that:

1. Docking velocities be minimized as much as possible. This is of primary importance.

2. Resilient rubber bumpers be substituted for the solid rubber blocks now connecting the wale to the pier.

3. Existing damaged 16-inch piles and existing piles of smaller diameter be replaced with new 18-inch butt diameter members.

4. Rubbing strips be installed on all piling.

5. Care be taken with the replacement piles to insure their being placed in line and parallel to the pier, and

6. Undamaged deep draft camels with minimum lengths of 50-feet be used exclusively during docking activities.

SCOPE

The scope of work for this project was directed at three general considerations:

1. Investigate the existing fendering system of Pier 5000 and determine the reasons for the unusually high rate of pile damaging along the north side of the pier.

2. Provide recommendations for the best method to increase the strength and resilience of the fender system.

3. Provide construction documents which detail the recommendations.

DISCUSSION

The investigative portion of the work included surface inspection of the fender system and discussion of docking activities and fender repairing procedures with the various concerned Naval personnel. On two occasions, the project structural engineer dove with scuba equipment to inspect the condition of the fender piling under the water and the condition of the deep draft camels.

Due to the lack of precise information, the tidal flow velocity was measured at two locations adjacent to the pier during a critical ebbing tide. The surface velocity was measured using a static drogue.

The project engineer was unable to observe actual docking procedure at the pier. However, the sequence was described to him verbally and assurance was given that the vessels were moved normal to the pier at the time of impact, and that the docking velocity could be controlled in spite of the tidal current.

Pertinent information determined from these inspections include the following:

1. Where the original 16-inch piles have been replaced, they have been replaced with 14-inch piles.

2. The metal rubbing strips originally installed on the piling are the type used with shallow draft camels, and are not completely effective with the deep draft camels used at this pier. As a result, damage and loss of cross section has occurred to the piling below the rubbing strips.

3. The metal rubbing strips have not been reinstalled on the replacement piling. The result has been damage to these piling along a considerable part of their length.

4. All of the original piles observed in the water have been damaged by marine borer activity to the extent that their strength has been significantly reduced beyond that recommended to resist the critical docking forces.

5. Many of the replacement piles have not been placed in line with each other or with the original piling. It is conceded to be a difficult problem to place a new pile in an intended position at this pier due to the length of the piles being used and the varying rate of tidal flow. Apparently, there is also a considerable problem in extracting the broken stubs of previous piling with existing equipment. However, with the realization that serious difficulties may exist in accomplishing the proper replacement of damaged piling, it is earnestly recommended that special effort be made to place these piles in line with each other.

6. Some of the deep draft camels currently in use have sustained damage and are considered to be unable to perform as required.

7. In the late morning of December 20, 1976, during an ebb tide which amounted to an elevation difference of 8.7 feet in approximately seven hours, the surface velocity was measured at two locations north of the pier. In line with the outer end of Pier 5000, the velocity was determined to be 1.15 feet per second. In line with the outer end of the new pier 5003, it was measured at 0.81 feet per second.

It becomes apparent that the best solution to the problem as defined above is not necessarily the ideal engineering solution. Consideration must be given to budget limitations, the necessity of keeping the pier in use during fender modifications, and need to accomplish the modifications quickly. Also, it is considered desirable to accomplish the solution with as little change to docking procedures and existing fender design as possible.

The principal recommendations are that the fendering system be modified to substitute a resilient rubber bumper for the solid rubber block which now separates the wale from the pier, and that 18-inch piles be installed. However, the total fendering system must include deep draft camels which are a minimum of 50-feet in length. This is most important. Otherwise, the computed docking energy cannot be dissipated properly and further breaking of piles will result.

For energy computations, docking velocity is taken as 0.5 feet per second at impact. This velocity is less than the recorded maximum tidal velocity. Therefore, during the time that the heavy ebb tide is flowing (1) there should be no docking of large vessels at the north side of the pier, or (2) the docking tugs must establish a speed upcurrent so as to reduce the velocity of impact.

Calculations were made to support the design conclusions of this report. The approach to the engineering solution is as recommended by Navy Manuals DM-25 and DM-26, with the exception that the mass of the vessel used in the energy computations is the actual mass of the largest vessel intended to be moored at the pier in the near future. This figure is taken as 8000 long tons, with no increase for the hydrodynamic mass. It is felt that for a vessel of the type being moored and an open pier, the difference between actual and virtual mass would be small. In any regard, the most important consideration in determining docking energy is the velocity of the vessel when impacting on the fender system, inasmuch as the energy varies as the square of that velocity.

The basis of the calculations on energy dissipation was taken to be that maximum stress which a sound pile of 18-inch butt dimension can be expected to take when subjected to an analogous concentrated load from a deep draft camel. The addition of the resulting pile deflection to those dimensions resulting from (1) the compression of the fender system, (2) the deflection and compression of the 50-foot camel, and (3) the deflection of the resilient rubber bumpers, results in the total distance through which the docking force is moved in order to dissipate the energy of docking.

The deflection of the wale at the docking location was investigated by computer to determine the magnitude of the resulting bending stress. These were determined to be within acceptable limits.

The use of an 18-inch pile with a 50-foot camel was selected as a more desirable alternative than a closer pile spacing of smaller piles and a shorter camel. The minimum number of piles acting during docking is six. This presumes that the piles have been placed properly and are in line parallel with the pier. Any pile not in line-to the front or to the rear-handicaps the proper functioning of the system. Too far forward it is deflected, and fails before adjacent

piles have assumed their proper load; after failure it leaves the system deficient of strength and resistance. Out of line to the rear, it never reaches its maximum loading until adjacent piles are deflected beyond their capacity. It is recommended, therefore, that exceptional care be used in placing these piles in line. It is suggested that a diver be used to confirm the pile tip location prior to driving the replacement pile.

The use of floating log camels in conjunction with deep draft camels should be discouraged as this provides a mechanism whereby the deep draft camel is compelled to rotate about the log and impact on the piling at a lower elevation with a concentrated force.

SECTION 2A
PIER TIMBER WORK AND TIMBER PILING

1. APPLICABLE PUBLICATIONS: The following publications of the issues listed below, but referred to thereafter by basic designation only, form a part of this specification to the extent indicated by the references thereto:

1.1 Federal Specifications:

VV-P-236	Petroleum, Technical.

1.2 American Wood Preservers Association (AWPA) Standards:

M-4-74	Standard for the Care of Pressure Treated Wood Products.

1.3 American Wood Preservers Bureau (AWPB) Standards:

MP-1-71	Standard for Dual-Treatment of Timber Piling Pressure Treated with Water-Borne Preservatives and Creosote - For Use in Marine Waters of Extreme Borer Hazard.

1.4 American Society for Testing Materials (ASTM):

A53-73	Welded and Seamless Steel Pipe.
A123-73	Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed, and Forged Steel Shapes, Plates, Bars and Strip.
A153-73	Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
A307-74	Low Carbon Steel Externally and Internally Threaded Standard Fasteners.
D25-73	Round Timber Piles.
D2000-70b	Elastomeric Materials for Automotive Applications.

2. SUBMITTALS:

2.1 Certificates: Before delivery of materials a certificate of compliance for the preservation and preservative treatment of piles shall be submitted to the Officer in Charge of Construction.

3. GENERAL REQUIREMENTS: The work shall include the removal of portions of the existing fender system consisting of piles, wales, chocks, and blocks and the furnishing of all necessary equipment and materials and performing of all labor for pier timber work, for all timber piling, and connections, all to be as indicated and/or specified for a complete job.

4. REQUIREMENTS:

4.1 Timber piles for all work shall be Douglas Fir and conform to ASTM Specification D25, Class A, 18-inch minimum butt diameter with 10-inch diameter tip. Piles shall be in one piece from point to butt. Piles shall be quality marked by the American Wood Preservers Institute. Piles shall be inspected at the place of treatment.

4.1.1 Timber piles shall be treated in accordance with AWPB Standard MP-1.

4.2 Rough hardware shall be zinc-coated steel. Bolts and nuts shall conform to ASTM A307. Steel plates shall conform to ASTM A36. Zinc coatings shall conform to ASTM A123 for steel plates and to ASTM A153 for threaded parts. Steel pipe shall conform to ASTM A53, Grade B, and shall be galvanized.

4.3 Washers shall be cast iron ogee washers of sizes which are standard for the bolts.

4.4 The lengths of bolts shall be such that not more than one (1) washer will be necessary under each head and under each nut to produce rigid connection. Bolts and nuts shall be finger fit.

4.5 Fender shock absorbers shall conform to size and configuration shown on the plans and shall conform to ASTM D2000, Class 3BA 720, A14, B13, D11, F17, and L11. They shall exhibit the following physical characteristics:

Tensile Strength, psi, min.	2000
Elongation, min.	600%
Shore Durometer	70 + 5
Modulus A 400% Elngation, psi	1000
Die B Crescent Tear PI @ RT	300
Water Absorption	0.2%
Coefficient of Friction, avg.	2.6
Compression Set	25%

5. CONSTRUCTION:

5.1 Fender piles shall be spaced accurately as shown on the plans, and shall be held during driving. Fender piles shall be protected during driving by suitable steel rings placed on the heads, or by approved driving caps. Heads and points shall be squared to the driving axis. Piles may not be water jetted. Piles shall be cut off to the elevations indicated. Pile heads at cut-off shall be entirely sound. All injured and rejected piles shall be moved and replaced with sound piles.

5.2 Precautions in Handling Treated Piles and Existing Timbers: Every effort shall be made in rafting and handling to prevent damage to creosoted piles and timbers, particularly in portions of the work exposed to marine borer attack. Care shall also be taken in driving piles to prevent checking or splitting of the treated wood, and butts shall be trimmed and headed so that the hammer will strike only untreated wood. Piles and timbers shall be inspected before and during the time they are driven or placed. Where the protective preservative shell is broken or damaged in any way, the holes and/or crevices shall be repaired by drilling, and neatly and tightly plugging the holes in accordance with AWPA Standard M4; where abrasions or other damages cannot be plugged, otherwise protected against marine borers in an approved manner; all work of this nature shall be subject to the approval of the Officer in Charge of Construction. All piles shall be handled in accordance with AWPA Standard M4.

5.3 Surface Treatment: The cut surfaces of all piles and timbers, including daps for chocks, clamps, braces, vales, etc., also counterbored holes and daps for washers, shall be treated in accordance with AWPA Standard M4.

5.4 Wood Preservative Treatment for Bolt Holes: Holes for bolts and plugs in all piles and all new holes in existing timbers of a nominal thickness of 6-inches or more, shall be treated to a sustained pressure of 120 psi with an approved mechanical bolt hole treater, using the same type of wood preservative specified for the member to be treated. All bolt holes in timbers having a nominal thickness of less than 6-inches shall be thoroughly flushed to saturation, using the same type of preservative specified for the member to be treated.

5.5 The repaired fender system shall consist of non-bearing creooted piles and existing treated timber chocks, installed as indicated. Heads of all piles shall be neatly and uniformly trimmed with a slight slope for drainage, and shall be treated in accordance with AWPA standard M4, and then painted with coal tar pitch. Piles and chocks shall be through bolted to inserts in the pier, except where otherwise shown.

5.6 Field Protection: After all members have been fastened or placed, bolt heads, washers, and nuts shall be given one full coat of petrolatum (grease) coating conforming with Specification No. VV-P-236. All surfaces to be coated shall be thoroughly cleaned and dried, and all nuts shall be drawn tight.

5.7 Removal of Existing Fender System: All designated existing fender timbers and fender piles shall be completely removed. Removal shall include the extraction of stubs of piles which have broken off below the mud line. No jetting will be permitted. Remove and put back various utility lines, ladders, and other dock hardware to the satisfaction of the Officer in Charge of Construction. Damage to coated surfaces shall be repaired using two coats to match present system.